Proposing fuel consumption limits for new vehicles to support Vietnam's Nationally Determined Contribution

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Received 29 April 2025; revised 25 May 2025; accepted 14 August 2025

Abstract:

Vietnam's Nationally Determined Contribution (NDC) sets a target of reducing total greenhouse gas emissions in the transportation sector by 34.33%, equivalent to approximately 15.66 million tonnes of CO_2, by 2030. This study was conducted to forecast the potential for achieving that target through the application of a fuel consumption limit for cars with fewer than nine seats and for motorbikes in Vietnam. The results show that the number of new cars increased rapidly from 159,289 vehicles in 2016 to 347,287 vehicles in 2022. Similarly, the number of new motorbikes increased from 2,917,086 units in 2020 to 3,202,554 units in 2022. The average fuel consumption of vehicles with fewer than nine seats and an average engine displacement of 1,748 cc was 6.98 L/100 km during the 2016-2022 period, while the average fuel consumption of motorbikes was 1.96 L/100 km. By applying an annual reduction rate in fuel consumption of approximately 4%, based on current levels, and under GDP growth scenarios ranging from 8 to 11% (forecast for 2025-2030), the total reduction in CO_2 emissions is projected to range from 15.73 to 16.53 million tonnes. This reduction would meet the target set in Vietnam's updated 2022 NDC.

Keywords: **CO_2 reduction, fuel consumption, greenhouse gas, Nationally Determined Contribution, vehicle emissions.**

Classification numbers: **5.2, 5.3**

1. Introduction

Economic development leads to increased energy demand and greenhouse gas (GHG) emissions. Many countries, such as Japan [1], China [2], Korea [3], and USA [4], have introduced standards on fuel consumption rates for new vehicles to control energy use and reduce emissions. Globally, various approaches are employed to limit GHG emissions. The most common include standards such as the Minimum Energy Performance Standard (MEPS), Corporate Average Fuel Economy (CAFE) and Corporate Average Fuel Consumption (CAFC), applied to automobile manufacturing and importing enterprises. CAFE is widely applied in European countries on a mass basis, and in the United States and Africa based on footprint, while CAFC is more commonly applied in Asian countries on a mass basis (Fig. 1). These standards aim to reduce light-duty vehicle petroleum consumption, GHG emissions and fuel costs by requiring automakers to produce more fuel-efficient vehicles [4].

Vietnam's GHG emissions are projected to reach approximately 868.5 $MtCO_2eq$ by 2030 [6]. The updated 2022 report on the NDC proposed ten solutions for the transport sector. Among these solutions, the "Fuel Consumption Limitation" measure is considered the most effective in reducing CO_2 emissions, accounting for up to 34.33% of the total targeted CO_2 reduction [7].

For solution E17 in the updated Vietnam NDC, the minimum fuel consumption levels for new vehicles are defined as follows: motorcycles, 2.3 L/100 km; passenger cars with engine capacity below 1,400 cc, 4.7 L/100 km; between 1,400 and 2,000 cc, 5.3 L/100 km; and above 2,000 cc, 6.4 L/100 km. This measure is

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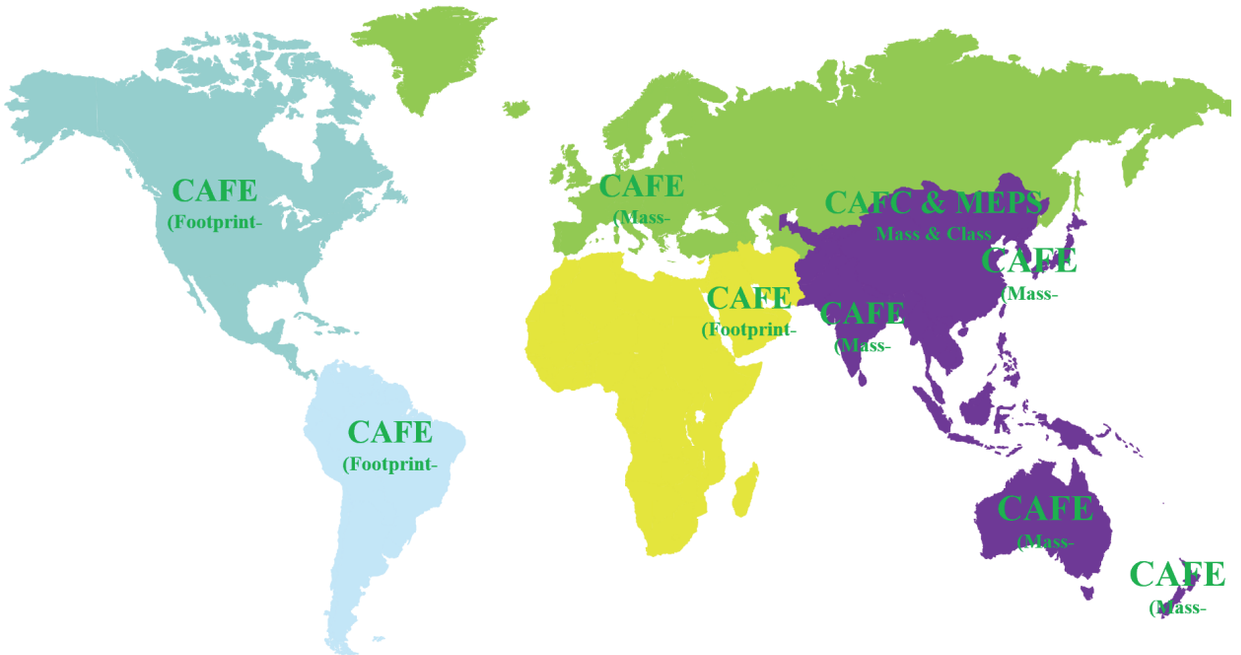

Fig. 1. Corporate average fuel economy/Corporate average fuel consumption standards applied around the world [5].

expected to reduce emissions by 15.66 million tonnes of CO_2eq by 2030. Thus, the solution "Limiting fuel consumption for newly manufactured, assembled and imported motor vehicles" is consistent with the targets across the NDC reports.

Vietnam currently regulates energy labelling for vehicles with seven to nine seats under Circular No. 40/2017/TT-BGTVT. The regulation on "vehicle energy labels" provides information on the type of fuel used and the vehicle's tested, certified or registered fuel consumption, helping consumers make informed choices about fuel efficiency. However, Vietnam has not yet implemented binding regulations on fuel consumption limits for passenger cars and motorcycles as proposed in the NDC scenario.

To assess the technical impact of the emission reduction target for vehicles with up to nine seats and for motorcycles, this study calculates GHG emissions for these vehicle types between 2022 and 2030 under a Business-As-Usual (BAU) scenario, assuming no additional supportive policies or emission-reducing technologies. It then calculates the emissions from 2026 to 2030 under a development pathway that applies solution E17 (the "E17 scenario"), which introduces a Fuel Consumption Limit. The difference in emissions between the BAU and E17 scenarios represents the potential reduction achievable through this measure.

2. Materials and methods

2.1. Materials

Data on the number of vehicles manufactured or imported during 2016-2022 were collected from the Vietnam Automobile Manufacturers Association (VAMA) for cars with fewer than nine seats, and for motorcycles during 2020-2022 from distributors. Information on engine displacement and fuel consumption of the vehicles in this study was self-reported by the manufacturers.

2.2. Methods

Method for collecting secondary data: Data on automobile fuel consumption were compiled, including the quantity of each car model and type of vehicle with up to nine seats that were manufactured, assembled or imported into Vietnam from 2016 to 2022, as well as motorcycles from 2020 to 2022. These data were used to establish the current baseline for fuel consumption standards.

Method for forecasting vehicle growth: The forecast for the number of vehicles was based on historical growth trends combined with projected GDP growth, while also taking into account government development policies. The forecast results used in this study are consistent with research conducted by the Ministry of Transport [8].

The method for forecasting the growth of cars with fewer than nine seats and motorcycles was based on interpolation from growth data between 2005 and 2022. Vehicle quantity data for this period were collected from the Vietnam Automobile Manufacturers Association (VAMA) for cars under nine seats, and from the Ministry of Transport [8] for motorcycles. The average annual growth rates for cars with fewer than nine seats and motorbikes during this period were 13.3 and 9.25%, respectively (Fig. 2).

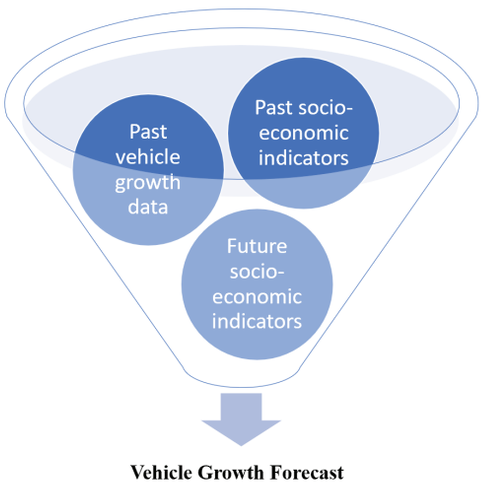

Fig. 2. Method for forecasting the vehicle growth by 2030.

Method for calculating CO_2 emissions:

$$CO_{2\_BAU}=n_{BAU} \times D \times CAFC/100 \times 2.408 \text{ [9]} \quad (1)$$

$$CO_{2\_E17}=n_{E17} \times D \times CAFC/100 \times 2.408 \text{ [9]} \quad (2)$$

in which:

- n_{BAU} and n_{E17}: number of vehicles under the BAU (Business-as-Usual, i.e. assumed emissions without mitigation policies) and E17 scenarios.

- D: average annual travel distance (15,330 km for a car; 7,400 km for a motorbike).

- CAFC: Corporate Average Fuel Consumption of cars and motorbikes.

- 2.408: CO_2 emission factor of fuel, kg CO_2/l, according to Ministry of Natural Resources and Environment (2022) [10].

The total reduction in CO_2 emissions is then calculated as:

$$CO_{2\_BAU}\text{-}CO_{2\_E17}$$

3. Results and discussion

3.1. Current status of fuel consumption

3.1.1. For cars with fewer than nine seats

The automobile market in Vietnam currently comprises around 42 enterprises engaged in the manufacturing, assembly and import of various types of vehicles, including passenger cars, buses and trucks. Among these, 30 enterprises are involved in the production, assembly or import of vehicles with up to nine seats. Of these, nine belong to the VAMA, while the remaining 21 operate outside the association.

Within the scope of this study, data were available for 27 popular car types. Data from 2016 to 2019 were sourced from the report "Developing a database on fuel consumption and determining the baseline fuel consumption for passenger vehicles under 9 seats," conducted in 2023 [11]. Vehicle data from 2020 to 2022 were collected from reports submitted by companies both within and outside VAMA. The details are presented in Fig. 3.

Fig. 3. Number of cars with up to 9 seats manufactured and imported during the 2016-2022 period.

The collected data cover more than 95% of new vehicle sales on the market during the study period, ensuring reliability. Statistics on the current fuel consumption status of vehicles in Vietnam are based on each manufacturer's reported figures for combined fuel consumption (L/100 km) and the number of vehicles produced or imported each year.

The calculation of the average fuel consumption standard was based on the number of vehicle types and their corresponding fuel consumption levels, using

a weighted average coefficient. The results show that the average MEPS value for vehicles with fewer than nine seats was 6.98 L/100 km during the 2016-2022 period. This figure is relatively high compared with the global average, for instance, 5.9 L/100 km in China [12], 5.2 L/100 km in Japan [11], 4.2 L/100 km in Korea and 5.9 L/100 km in Saudi Arabia [13]. The average engine displacement was 1,748 cc. The specific statistical results are presented in Table 1 and Fig. 4 below.

Table 1. The average fuel consumption of cars with fewer than nine seats.

No	Car types	Total, unit	Fuel consumption (L/100 km)	No	Car types	Total, unit	Fuel consumption (L/100 km)
1	Type 1	1,796	7.81	15	Type 15	334	10.70
2	Type 2	9,529	7.48	16	Type 16	35	10.91
3	Type 3	19,202	6.38	17	Type 17	331	12.28
4	Type 4	49,204	6.83	18	Type 18	540	9.08
5	Type 5	32,810	6.29	19	Type 19	1	12.80
6	Type 6	26,797	6.74	20	Type 20	15	12.24
7	Type 7	5,451	9.05	21	Type 21	3	8.03
8	Type 8	64,840	7.13	22	Type 22	461	7.76
9	Type 9	14,517	7.73	23	Type 23	12	13.16
10	Type 10	8,180	6.28	24	Type 24	1	7.63
11	Type 11	1,331	6.12	25	Type 25	787	7.36
12	Type 12	4,536	7.34	26	Type 26	2,200	8.56
13	Type 13	1,035	10.64	27	Type 27	323	7.26
14	Type 14	6,161	7.27	Average fuel consumption			6.98

Table 1 presents statistics on the current distribution of engine cylinder capacity for vehicles in Vietnam, based on manufacturer-reported data on engine size (cc) and the number of vehicles produced or imported each year. The results indicate that most vehicles with an engine displacement greater than 1,400 cc have fuel consumption levels above the overall average of 6.98 L/100 km. Specifically, the fuel consumption rates for vehicles with engine capacities below 1,400 cc, between 1,400-2,000 cc and above 2,000 cc are 5.3, 6.9 and 8.6 L/100 km, respectively.

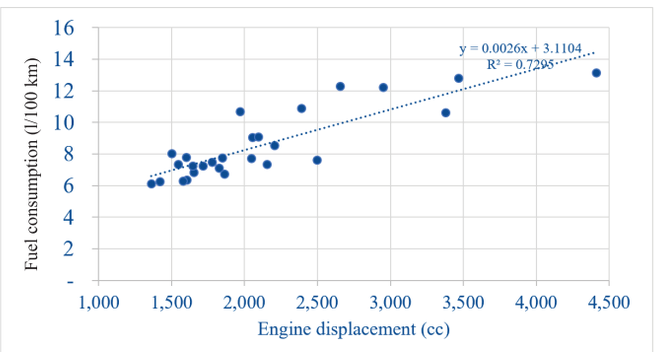

Fig. 4. Fuel consumption based on engine displacement.

Figure 4 shows that the majority of passenger cars in Vietnam fall within the 1,400-2,000 cc engine displacement range, accounting for approximately 65.01% of the total. Vehicles with an engine displacement below 1,400 cc represent 19.65%, while those with a displacement above 2,000 cc account for 15.33%.

3.1.2. For motorcycles

At present, the Vietnamese motorcycle market is served by nearly 80 manufacturers, assemblers and importers of various types of motorcycles and scooters. Within the scope of this study, data were obtained from 35 companies, of which five belong to the Vietnam Motorcycle Manufacturers Association, while the remaining 30 operate independently of the association. Data from these 35 companies, covering the period 2020-2022, are presented in detail in Fig. 5.

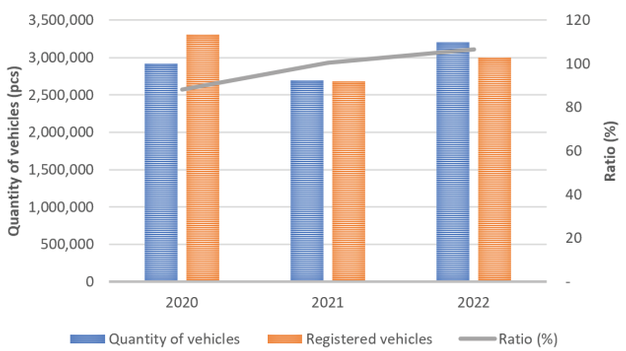

Fig. 5. Number of motorcycles on the market over the years.

Statistics on the current fuel consumption of the motorcycle fleet in Vietnam are based on manufacturer-reported data on combined fuel consumption (l/100 km) and the number of vehicles produced or imported each year. The average fuel consumption value was calculated using the number of motorcycles and their corresponding fuel consumption levels, following the same method applied to determine the average fleet mass of motorcycles as previously described. The specific statistical results are presented in Table 2 and Fig. 6.

Table 2. The average fuel consumption of motorcycles.

No	Motorcycle type	Total units	Fuel consumption (L/100 km)	No	Motorcycle type	Total units	Fuel consumption (L/100 km)
1	Type 1	2,179,657	1.99	19	Type 19	1,072	2.14
2	Type 2	471,031	1.91	20	Type 20	784	1.87
3	Type 3	39,350	1.86	21	Type 21	2,245	1.74
4	Type 4	21,885	2.60	22	Type 22	2,847	1.28
5	Type 5	28,299	2.59	23	Type 23	2,012	2.29
6	Type 6	675	2.24	24	Type 24	3,321	1.16
7	Type 7	6,248	2.90	25	Type 25	222	5.04
8	Type 8	51,226	2.33	26	Type 26	558	2.05
9	Type 9	11,006	1.29	27	Type 27	147	3.12
10	Type 10	9,915	1.64	28	Type 28	2,983	1.38
11	Type 11	9,831	3.75	29	Type 29	4,929	2.06
12	Type 12	13,322	1.49	30	Type 30	1,659	2.19
13	Type 13	5,295	1.50	31	Type 31	2,673	2.23
14	Type 14	1,460	5.01	32	Type 32	1,369	1.87
15	Type 15	6,345	1.32	33	Type 33	766	1.95
16	Type 16	26,396	1.42	34	Type 34	2,241	2.17
17	Type 17	21,341	2.10	35	Type 35	367	1.50
18	Type 18	2,367	2.06	Average fuel consumption			1.99

The average fuel consumption of the motorcycle fleet in Vietnam over the three-year period from 2020 to 2022 was 1.96 L/100 km. This result is consistent with the findings of D.S. Tran, et al. (2022) [14] and is significantly lower than the predicted value in the NDC, which is 2.3 L/100 km.

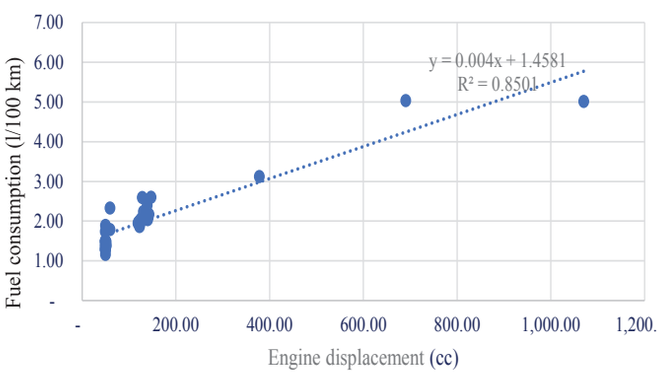

Fig. 6. The fuel consumption and engine displacement of motorcycles.

3.2. Assessment of the ability to achieve emission reduction targets

To meet its commitment to reducing greenhouse gas emissions, the updated 2022 report on the NDC proposed ten solutions for the transport sector. Among these, solution E17, "Fuel Consumption Limitation (FCL)", is considered the most effective, contributing 34.33% of the total targeted CO_2 reduction. By 2030, the minimum fuel consumption levels proposed for vehicles sold on the market are: 2.3 L/100 km for motorcycles and scooters, 4.7 L/100 km for passenger cars with engine capacity below 1,400 cc, 5.3 L/100 km for mid-size cars (1,400-2,000 cc); and 6.4 L/100 km for large cars (>2,000 cc). This measure is expected to reduce emissions by 15.66 million tonnes of CO_2 equivalent.

When compared with the E17 targets, the current average fuel consumption of vehicles with engine capacities below 1,400 cc, between 1,400-2,000 cc and above 2,000 cc is higher by 10, 24 and 26%, respectively. To achieve the NDC target for 2030, and to progress towards Net Zero by 2050, the required average annual reduction in fuel consumption is estimated at 4% per year for passenger cars and 2% per year for motorcycles. These values are based on the difference between the Business-as-Usual baseline and the E17 target scenario, applied for the period 2026-2030. Such reduction rates are comparable with international experience: the United States (4.7%/year), China (5.5%/year) and Japan (3.7%/year) [15].

3.2.1. Growth forecast scenario

The forecast of vehicle numbers to 2030 is drawn from the Ministry of Transport report published in 2019 [8]. This forecast is based on historical vehicle growth data (2005-2022), along with past and projected socio-economic indicators. The forecasted data on vehicle numbers to 2030 are presented in Fig. 7 and Table 3 below.

For low growth scenario: It is forecast that by 2030 the total number of automobiles nationwide will reach approximately 11.35 million vehicles, with an annual growth rate of 10.8% during 2022-2030. Of these, cars with up to nine seats are expected to reach around 8 million vehicles, growing at 12.9% per year. The number of motorcycles in circulation is projected to reach about 63 million units, corresponding to an annual growth rate of 2.9%. By 2050, the total number of automobiles nationwide is forecast to reach approximately 25.9 million, with an annual growth rate of 4.2% during

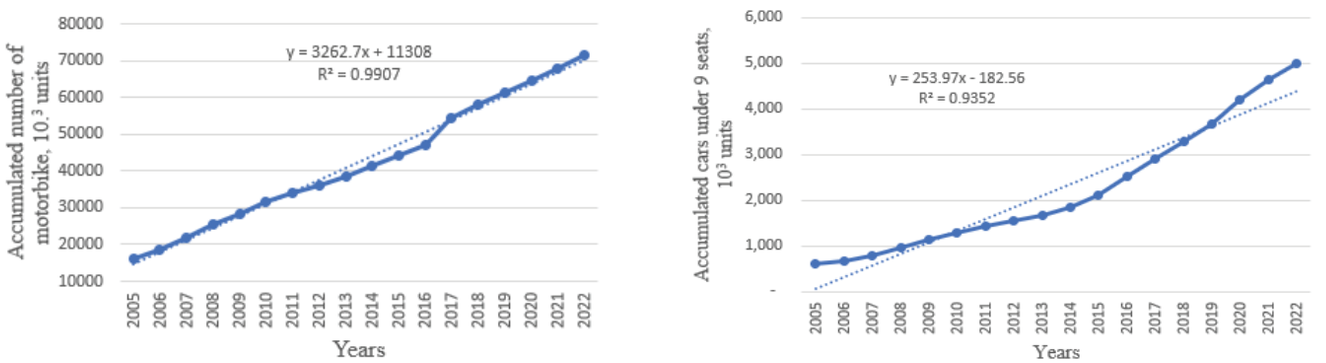

Fig. 7. Vehicle growth chart 2005-2022 period.

Table 3. The forecasted number of cars by 2050 [8]. *Unit: 1000 pcs.*

Year	Total*		Car under 9 seats		Passenger car		Truck		Other		Motorcycle	
	LGS	*HGS*	*LGS*	*HGS*	*LGS*	*HGS*	*LGS*	*HGS*	*LGS*	*HGS*	*LGS*	*HGS*
2025	6,420	7,170	4,100	4,600	220	250	1,900	2,100	200	220	57,000	60,000
2030	11,350	12,560	8,000	8,900	300	330	2,750	3,000	300	330	63,000	66,000
2040	20,920	22,580	15,700	17,000	420	450	4,300	4,600	500	530	67,000	70,000
2050	25,900	28,760	19,500	22,000	350	380	5,500	5,800	550	580	70,000	72,000

*Except motorcycles, LGS: Low growth scenario, HGS: High growth scenario.

2031-2050. Among these, cars with up to nine seats are expected to account for around 19.5 million vehicles, growing at 4.6% per year, while the motorcycle fleet is projected to reach about 70 million units (Table 3).

For high growth scenario: By 2030 the total number of automobiles nationwide is expected to reach approximately 12.56 million vehicles, with an annual growth rate of 12.3% during 2022-2030. Of these, cars with up to nine seats are projected to reach about 8.9 million vehicles, growing at 14.4% per year. The number of motorcycles in circulation is forecast to reach around 66 million units, with an annual growth rate of 3.5%. By 2050, the total number of automobiles nationwide is expected to reach approximately 28.76 million, with an annual growth rate of 4.8% during 2031-2050. Among these, passenger cars are projected to account for about 22 million vehicles, growing at 5.2% per year, while the motorcycle fleet is forecast to reach about 72 million units (Table 3).

3.2.2. CO_2 emission reduction scenarios

To assess the technical impact of the emission reduction target under the E17 measure for passenger cars with up to nine seats and for motorcycles, this study calculated the greenhouse gas (CO_2 as a representative) emissions of these vehicle types from 2022 to 2030 under two scenarios. In the BAU scenario, no additional policy support or deployment of emission-reducing technologies is assumed (Equation 1). Subsequently, CO_2 emissions of these vehicle types will be calculated for the period from 2022 to 2030 under a development scenario that applies the E17 solution (referred to as the E17 scenario). This solution stipulates a Minimum Energy Performance Standard (as shown in Equation 2). The difference in emissions between the BAU and E17 scenarios represents the CO_2 emission reduction potential of the CAFC solution.

Under the BAU scenario-where no fuel consumption standards are applied-the total cumulative CO_2 emissions from new cars with up to nine seats during 2021-2030, corresponding to GDP growth rates of 8, 10 and 11%, are projected to be 51.87, 53.37 and 54.61 million tonnes, respectively. The total cumulative CO_2 emissions reduction from new motorcycles is estimated at approximately 63.07 million tonnes (Fig. 8).

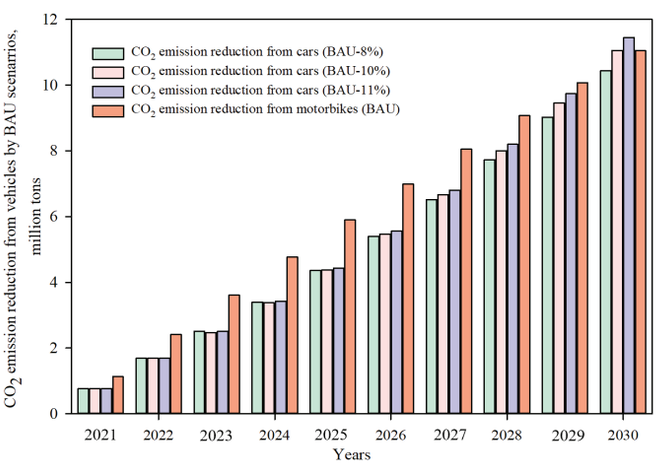

Fig. 8. CO_2 emission reduction from vehicles by Business-As-Usual scenarios.

Figure 9 illustrates the estimated CO_2 emission reductions from newly registered cars with up to nine seats and motorcycles during the 2021-2030 period, assuming the implementation of fuel consumption limits. With a reduction rate of 4% per year (applied from 2026), the total cumulative CO_2 emissions from new cars during this period are projected to be 42.88, 44.02 and 44.81 million tonnes under GDP growth scenarios of 8, 10 and 11%, respectively. For new motorcycles, the total cumulative CO_2 emissions are estimated at approximately 56.34 million tonnes.

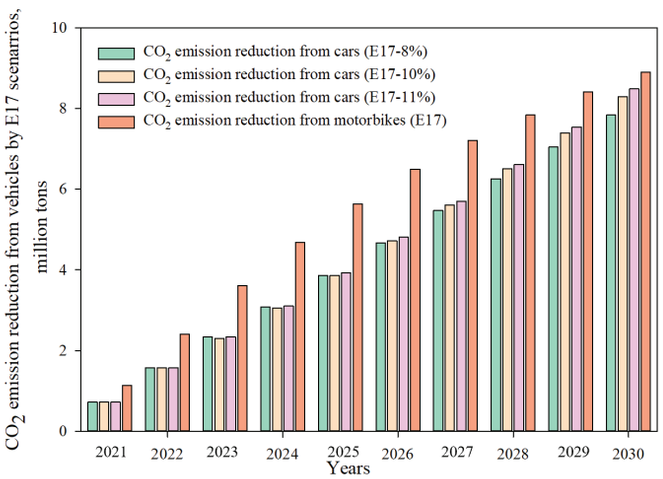

Fig. 9. CO_2 emission reduction from new vehicles by E17 scenarios.

The results indicate that by applying annual fuel consumption reduction rates of approximately 4% for passenger cars and 2% for motorcycles (E17 scenario), based on current consumption levels under the BAU scenario, and with forecast GDP growth of 8-11% for the 2025-2030 period, the total reduction in CO_2 emissions will range from 15.73 to 16.53 million tonnes. This outcome meets the target set in Vietnam's updated 2022 NDC.

4. Conclusions

While many countries have already adopted CAFE/CAFC standards for new vehicles, Vietnam has not yet implemented binding fuel consumption limits. At present, manufacturers and importers are only required to disclose vehicle fuel consumption rates to provide consumers with information that may guide their choice of more fuel-efficient models. Vietnam's updated NDC (2022) proposed several solutions for the transport sector to reduce CO_2 emissions. The early adoption of fuel consumption limits would not only deliver immediate benefits in lowering GHG emissions and supporting the national goal of net-zero emissions by 2050, but would also encourage manufacturers to improve fuel efficiency, accelerate the application of carbon credit policies and promote the uptake of environmentally friendly technologies such as electric and hybrid vehicles.

Table 4. CO_2 emission reductions from vehicles between the BAU and E17 scenarios by 2030. *Unit: million tons.*

No	Economic growth scenarios	Car under 9 seats		Motorbikes		Total emission		CO_2 emission reduction
		Business-As-Usual	*E17*	*BAU*	*E17*	*BAU*	*E17*	
1	GDP 8%	51.87	42.88	63.07	56.34	114.94	99.21	15.73
2	GDP 10%	53.37	44.02			116.44	100.36	16.08
3	GDP 11%	54.61	44.81			117.68	101.15	16.53

The greenhouse gas (GHG) emission reduction target stated in the updated 2022 NDC is up to 34.33% of total emissions from the transport sector, equivalent to 15.66 million tonnes of CO_2. As shown in Table 4, with the implementation of fuel consumption limits for cars with up to nine seats (4% reduction per year) and newly registered motorcycles (2% reduction per year) from 2026, the reduction in CO_2 emissions by 2030 is projected to be 15.73, 16.08 and 16.53 million tonnes under GDP growth scenarios of 8, 10 and 11%, respectively.

The results of this study show that, with GDP growth targets ranging from 8% to 11%, reducing fuel consumption in new vehicles by 4% per year for cars and 2% per year for motorcycles (applied during 2026-2030) could cut between 15.73 and 16.53 million tonnes of CO_2. This reduction fully meets Vietnam's updated 2022 NDC target of 15.66 million tonnes of CO_2 by 2030 and provides a solid foundation for the country's transition towards net-zero emissions by 2050.

CRediT author statement

Nguyen Ngoc Tu: Methodology, Supervision, Writing original draft, Editing; Trinh Quang Huy: Validation, Data analysis, Reviewing and Editing; Dinh Trong Khang: Data analysis, Investigation.

ACKNOWLEDGEMENTS

This study was funded by the Ministry of Transport, under Decision No. 1679/QD-BGTVT, dated 22/12/2023, on Issuing the Ministry of Transport's Plan to implement the Action Program on green energy transition, carbon and methane emission reduction in the transport sector.

COMPETING INTERESTS

The authors declare that there is no conflict of interest regarding the publication of this article.

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